REPORT ON IRRIGATION

IN THE

BHARATPUR STATE,

BY THE

CONSULTING ENGINEER FOR IRRIGATION

WITH

NOTE BY MR. J. A. DEVENISH, EXECUTIVE ENGINEER, P. W. D.

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APPENDICES.

REPORT ON IRRIGATION IN THE BHARATPUR STATE.

1. *Physical Aspects.*—The general appearance of the State is flat and rather low, especially towards the north, the average height of the surface being about 600 feet above the sea, and about 50 feet above the water surface of the Jumna.

The uniform character of the country is interrupted by detached hills in the north and south, and by low ranges on some parts of the western and south-eastern frontier, but the general aspect is an alluvial plain, fairly wooded.

In the rains, owing to the low level, a considerable amount of surface is flooded. The soil of a great part is hard and dry, and in places much deteriorated by sand.

The State, it is said, suffers from want of water, but much has been done of late years to remedy this, and the land is made productive by the industry of its inhabitants.

The principal hills of the State are a low range forming the boundary of Bharatpur, Ferozepur and Alwar, running north and south, the highest point of which, Chapra, is 1,222 feet. The Sidgirpahar range runs on the south-eastern frontier in a direction north-east to south-west for a length of about 30 miles, the highest point, Usera, being 817 feet. This range becomes broken in the southern part, helping to form the district called the "Dang."

2. The State has no perennial rivers. The principal rivers are the Bangunga or Utangan, rising in Jaipur and flowing through Bharatpur from west to east; the Ruparel, rising in Alwar territory; the Gambhir, rising in Karauli and passing through a part of the Jaipur State, and Kakand rising in Karauli. The last two are subject to sudden rises.

3. Bharatpur is the only Jat principality of any magnitude in India, and perhaps the only State in India where a great proportion of the people belong to the same race as the nobles and princes.

4. The following extract from the Report of the Irrigation Commission gives a brief and good account of the State (Part II, page 216):—

"Out of one million acres available for cultivation, 75 per cent. is cultivated, and of the cultivated area 24 per cent. is irrigated annually. The State is therefore fairly well protected by Irrigation. During the past 5 or 6 years a good deal of good work has been done in constructing new and repairing old Irrigation Works. By an expenditure of slightly over 10 lakhs, the area annually irrigated by the State's works has been increased by over 50,000 acres. The works, besides being of great benefit to the cultivator, are a source of considerable profit to the State, for they yield annually Rs. 40,000 in water rates, and are said to have increased the annual land revenue by 2½ lakhs during the past 6 years. The country affords unusual facilities for Irrigation, and the works are of a simple and inexpensive character. They consist chiefly of embankments or

bunds carried along a contour or across a shallow depression, with the object either of impounding and distributing spill waters from neighbouring torrents, or of impounding the surface flow from local catchments. The country is too flat to admit of any prolonged storage of water. There is in fact only one tank in the State in which water is kept in store after the sowing of the winter crops. The main object of the *bunds* is to submerge the land above them, so as to fertilize the soil by the deposited silt, and saturate it for the autumn sowings. The land being flat, a low bank floods a large area. The Ajan Bund, an earthen bank 12 miles long, intercepts the spills of the Banganga River, and submerges about 14 square miles of country, the depth of water being nowhere more than 10 feet. When there is water to spare during the rains, or when, after the rains, it is being drawn off to prepare the land for sowing, it is utilized to saturate the land below the embankments. Indirectly the works are of great utility in sweetening the often brackish sub-soil water and in maintaining the supply of wells."

5. *Sources of Irrigation.*—Inundation or Irrigation is obtained from the sources and means described below, *viz*:—

(*a*) From torrential streams, either by natural spill or by means of inundation canals and training banks.

(*b*) From local drainage intercepted by bunds or embankments.

(*c*) From wells.

6. The system of Irrigation throughout the Bharatpur State is to ultilise the floods for inundating the land during the rainy season, when the soil becomes thoroughly saturated a slight deposit of silt which possesses highly fertilising properties being also left on the surface by the floods.

After the rainy season the water is drained off, and the flooded land is ploughed and sown for the winter crop.

Further Irrigation is unnecessary. The winter rains assist in producing a heavy crop. If they fail, the crops are light, or well irrigation is resorted to.

7. The following notes are taken from a report submitted by Mr. J. A. Devenish, State Engineer, to the Irrigation Commission, who deserves great credit for the capital work he has done for the State.

"Most of the old Irrigation Works, consisting of embankments and sluices, appear to have been constructed in the time of Maharaja Balwant Singh (1834 A.D.), who must have had great interest and ability for such works, or was well advised, for the works dating from this period were planned on a bold scale, and though lacking scientific design, fulfilled their purpose as long as they were kept in good repair and their occasional failures remedied.

"There are two long embankments, each now 12 miles or more in length, which were commenced at that time, each impounding and distributing the floods received from torrents, having more than 1,000 square miles of drainage area. Besides these, there must have been nearly 100 or more small embankments or bunds built to impound local catchments

these often crooked and uneven, but well placed and effective to catch the drainage, until a larger flood than usual breached them, when the gaps were mended to make the bund fairly serviceable again.

"These works were kept in good order during the time Captain F. J. Home, R.E., was State Engineer, and much was done to improve them. Masonry escapes were provided for the larger bunds, the construction of a new large storage reservior was begun, and some drainage channels had been constructed, when the further progress of these works was interrupted by the accession to full power of the late Maharaja Jeswant Singh, who cared for none of these things (A.D. 1867).

"When the State came again under administration in A.D. 1894, it was decided to reorganize the State Public Works Department, and Mr. J. A. Devenish, Executive Engineer, was appointed in November 1894, with special instructions to conserve the water supply, the waste of which had attracted much attention owing to the frequent swamping of British territory, by floods escaping through a large breached training bank, known as the Ajan Bund, across the border into the Agra district. The damage caused by these unrestrained floods had formed the subject of more than one Government enquiry and of a vast deal of correspondence.

"The outskirts of the Bharatpur city also suffered from swamping, which, unrelieved by drainage, rendered the land unculturable, and made the place notoriously unhealthy. As soon as a preliminary inspection and survey of the Irrigation Works had been completed, the Executive Engineer found that nearly all of them were breached, and that all but a very few had been abandoned. Some use was made of the floods escaping through the breaches of the Sikri Bund, but with this exception there was no cultivation depending on artificial irrigation by bunds or channels. Large tracts of country were over-run with wild cattle, so that it was hardly worth while attempting cultivation in some 200 affected villages. In 1895 a commencement was made of restoring and improving the old works. a large breach in the Sikri Bund being first repaired in time for the floods of that year. The breaches in the upper part of the Ajan Bund were also closed at the same time, and the injurious flooding of British territory thereafter ceased. As demands were received, detailed projects were prepared, and the restoration of the most useful of the minor works were taken in hand. In 1895 the Executive Engineer, after observing the course of the Banganga floods of the preceding year, perceived that it was possible to spread them out over land comparatively high and hitherto unflooded, by making a cut through an intervening ridge, thus at the same time relieving areas hitherto flooded excessively. This high land was mostly waste, owing to the saltness of the wells and to the wild cattle nuisance. The cut, which was at first made 20 feet wide, was found to be extremely successful, the water diverted being used with avidity by the owners of the land thereby commanded. This cut, which is known as the Oochain Canal, was subsequently enlarged gradually to a

width of 50 ft., and a system of subsidiary works, such as training banks and flood regulators to feed it and minor reservoirs depending on it, were constructed.

"The success of this work, which in 1900 irrigated 11,500 acres (the total capital cost, including all subsidiary works, being only Rs. 70,000 up to that date), gave encouragement to the construction of other channels to distribute the Banganga floods, all of which have proved to be increasingly successful as the works connected with them are developed."

Cuts have been taken out from the Banganga River from five different points, and from the Gambhir Rivers at three points. Any water derived from the rivers by natural spill is also utilized. During the years 1895-1900, the large bunds such as the Sikri and Ajan Bunds have been continuously raised, strengthened, extended and improved by the addition of new masonry works, while distributing channels from the sluices have been and are still being constructed. The Consulting Engineer inspected the land affected by the floods from the Banganga and Gambhir. As far as the eye could reach, the country was covered with fields of ripening grain, all due to the proper distribution of the flood waters of these rivers. Mr. Devenish deserves great credit for all these works, and the results are most encouraging.

Nearly all the smaller works have been restored and improved. There are perhaps 10 per cent. of them remaining worthy of attention.

8. There is still a good deal of work to be done in improving the distribution of the floods, the goal aimed at being the entire utilisation of the floods reaching the territory, which can be effected by judicious regulation and by subsidiary works to afford more control.

9. There is only one large storage reservoir which deserves separate notice. This is the Bareta Bund, which was originally designed and nearly half built by Captain Home, R.E.

This was completed in 1897 according to a revised design by Mr. Devenish, and since then ducts have been added and several improvements made to render the work more secure. Owing to a rocky catchment and an excellent basin, this work has proved unusually successful for a work of its class. The catchment area is about 70 sq. miles, the maximum depth 40 ft., and a waterspread of 4 square miles when full. The basin, which holds 1,500 million cubic feet, filled to overflowing in 1898, and has been nearly filled in the other years since the completion of the work, the rainfall not exceeding 25 inches. The cost, including all subsidiary works, but excluding the expenditure on it before the work was abandoned, has been about 2½ lakhs. In 1900, 3,000 acres were irrigated from it. The irrigated area when developed will extend, it is hoped, to 10,000 acres. The influence of this large reservior on the surrounding country has been remarkable, a considerable tract of waste land having come into occupation. Irrigation from this work takes place continuously for both the Rabi and Kharif crops.

10. The following is an abstract of areas irrigated in A.D. 1900, and the capital cost, as far as it is known, of the works on which they depend :—

	Area, Acres	Cost, Rs.	Remarks.
(*a*) Irrigated by channels from the Banganga and the Gambhir and subsidiary works, including the Ajan Bund.	33,500	3,55,000	Not including cost of the Ajan and Sikri Bunds before they were restored in 1895-1901, the original expenditure not known.
(*b*) Irrigated by the Sikri Bund and subsidiary works.	30,000	2,40,000	Not including Rs. 70,000 expenditure incurred before the work was abandoned in A. D. 1867.
(*c*) Irrigated by the Bareta Bund (the only storage reservior in the State.)	3,000	2,27,054	
(*d*) Irrigated by local catchments (village bunds).	15,000	1,82,362	Not including original cost of works abandoned previous to their restoration.
	82,393	10,04,416	

The areas quoted are those actually assessed after cultivation.

These figures are exclusive of establishment charges, which do not exceed 15 per cent. on the total expenditure.

11. The Bangunga River spills freely over its northern bank as it passes through the State ; and about midway in its course eastward the river has left its old channel, and now flows in a northerly direction towards Oochain, along the Byana-Oochain Road. This road is carried on a raised embankment from Nekpur to Sewar, with flood regulators and sluices at intervals ; and at Oochain a canal 50 feet wide has been cut, running parallel to the road, which leads a portion of the floods northward to Sewar and the vicinity of the Bharatpur city.

The larger portion of the floods are, however, released at various points along the Byana-Oochain Road, through regulators discharging in an easterly direction.

The flood water so discharged is impounded again and distributed by other works, the largest of which is the Ajan Bund, a fine embankment extending for 12 miles across the direction of flow.

The Ajan Bund, which commands the whole vicinity of the Bharatpur city, contains a number of sluices and weirs, through which the flood water can be released to irrigate the land in rear during flood time, and the sluices are also employed to empty the basin, which has a contour area of 14 square miles.

Until recent years the inundations from the Banganga were more or less uncontrolled, and were a cause of much loss to the State and to British territory beyond, instead of being as now a valuable source of prosperity. The old works had been abandoned in a breached condition, flooding took place in natural depressions, which thereby became uncultur able, while the higher land on the margin remained unirrigated.

It may be interesting to note here, that formerly the inundations from the Banganga did so much damage to lands in British territory that they formed the subject of repeated complaint and much correspondence. So long ago as 1865, Col. Brownlow, R.E., who was sent to report upon the subject says: "In my opinion it is now too late to attempt the control of the river at a point so far down its course as Koorka, and the only effectual method left for the purpose is the establishment of large reservoirs near its source."

The town of Bharatpur is situated in a depression several feet below the level of the Banganga, and there was always the danger of the town being some day inundated, in fact, more than once precautions had to be taken to keep the water out.

Now, owing to the judicious way the inundations have been controlled and distributed and stored, the damage alluded to above has been prevented, the safety of the city has been secured, and profit is derived from what originally was a source of loss. This is a good object lesson of how a river of this sort may be successfully controlled.

12. The Gambhir River has well-defined banks, and does not spill largely until it enters the old bed of the River Banganga. The silt of this river is said to be (unlike the silt of the Banganga) highly fertile, and crops are grown in the river bed after the rainy season. The Gambhir is made to spill largely into the Rupbas Pergunnah at the east of the State by means of natural and artificial channels at Dhana, Ghata, Bokholi and Shahpur, all taking out from the southern bank. There is also a considerable natural spill from the northern bank.

In 1900 about 1,500 acres were benefited by natural or artificial spill from the Gambhir. Irrigation Works to develop the system are in progress, and in 1901 several thousand acres have been flooded.

13. The floods from the Ruparel as they enter the State are diverted by the Sikri Bund, a fine embankment which extends for 12 miles along the western boundary, so that they do not follow the old river valley, but are distributed through sluices at intervals, mainly in an easterly direction, over the Pergunnahs of Pahari, Gopalgarh and Nagar, the distribution of the water being effected by a system of distributary channels from the sluices and shallow subsidiary reservoirs fed by these channels, on which the Durbar has lately spent about two lakhs of rupees.

The Irrigation derived from these floods is a valuable source of prosperity, the area of the crop irrigated in a good year amounting to 30,000 acres or more.

The Alwar State claims half the share of the Ruparel water by the agreement made and sanctioned in 1837 A.D., and the case, which has been a matter of dispute for 100 years or more, is now under reference.

14. The system of Irrigation appears to be very complete in the Bharatpur State, nearly all the available catchments being impounded, so that only a small proportion of the local rainfall escapes beyond the State, and that only in the sparsely inhabited ravine tracts in the southern extremity.

The catchments impounded vary in size from ½ square mile to 10 square miles, but the typical size may be said to be about 1½ sq. miles, intercepted by a low earthen bank more than a mile in length; the depth does not usually exceed 7 ft. There are more than 100 of these works.

15. In 1900 the area of crop irrigated by small bunds having catchment areas less than 12 sq. miles amounted to 19,000 acres, and though this is small in comparison with the area irrigated by inundations, yet the influence of these small works in contributing to the contentment and prosperity of the villages is considerable. The bund protects the best land in the villages and keeps up the water level. It is sound policy to carefully improve and maintain such works. There are still some 20 to be restored.

16. *Wells.*—A good deal of Irrigation is done by wells throughout the State. In the dry season the depth to the water surface is about 33 feet below the ground level on an average. Many of the wells, especially those in the central Pergunnahs are bitter.

According to the last Settlement Report there are 106,000 acres of land irrigated by wells—11,610 are sweet wells and 5,852 bitter. The quantity and quality of the water in the wells are much improved by yearly inundations.

17. *Jhils.*—The main fall of the country is easterly towards the junction of the Jumna and Chambal River, the fall being at the rate of about 5 feet in the mile.

The swamps in the extreme north are, it is said, undrainable, except easterly towards the British districts of Muttra, as the old Ruparel valley, along which the swamps lie, has become silted up owing to the diversion of the stream. An artificial cut would be required to drain it.

The swamping of the valley has, however, been obviated recently by the restoration of the Sikri Bund, which now intercepts the Ruparel floods, so that the swamps which were caused by these floods, no longer exist permanently.

The Keladeo Jhil, 3 miles south of the city, is a notable depression, flooded annually from the River Banganga *via.* the Ajan Bund. The Jhil is now drained, so that water can be stored in it to any desired depth, and it is partitioned by small embankments, so that each part can be flooded separately.

Other parts of the State, which formerly suffered from excessive flooding, have now been relieved by diversion of the floods or by drainage. Unless the floods are controlled, the environs of the city may lie in swamp throughout the greater part of the year. It is now possible to control the floods so that only a moderate inundation of the low-lying land to the south-west of the city is allowed. From this source, as soon as the flood water has become fairly clear, the Fort moat is annually filled.

Mr. Devenish till recently was Executive or State Engineer. Knowing the good work he had done for the State, the Consulting Engineer thought it would be well to take advantage of his local knowledge and experience, and so asked him to prepare a Note on the future requirements and possibilities of Irrigation in the Bharatpur State. This he has kindly done. These papers ought to be a great help, and with the hope that they may be, they have been printed and are attached. (Appendix A)

These papers and the Memoranda submitted by Mr. Devenish to the Irrigation Commission describing fully Irrigation in the State, show the interest he took in the subject. The success which has attended his efforts reflect great credit on Mr. Devenish.

The Consulting Engineer for Irrigation visited Bharatpur on the 9th March 1904, and in company with Mr. Judd, the State Engineer, visited several places of interest. His remarks on each place visited and on the proposed supply of good drinking water to the city are noted in the Appendix to this report.

Mr. Devenish, the late State Engineer, was with them part of the time. It was encouraging to him, as it was to the others, to see such happy results from his work.

Mr. Judd, his successor, takes an equally keen interest in Irrigation, and there is no doubt, under him and his *locum tenens*, Mr. Burke, every effort will be made to sustain the reputation of the State, and that it will be successful.

18. The following points in Mr. Devenish's Note on the future requirements and possibilities of Irrigation are deserving of consideration. Some, it will be noticed, have been already carried out and some are in hand :—

(1.) Improvements required in the cuts already made from the River Banganga, principally by extending them and by making low banks, to form shallow reservoirs in which the flood supply can be retained over the field. (Para. 4).

(2.) *The Ooloopura Canal.*—A new mouth to be made further up stream, the canal to be widened, the bed lowered and falls put where necessary, the object being to fill the large Ataripura Bund and to flood the land on the way, at the same time not to spend too much money on this work until all the other canals have been improved to their full capacity. (Para. 5).

(3.) *The Pathena Canal* (Para. 6).—To be brought up to proper section and subsidiary shallow reservoirs be formed in suitable places to store the flood water, *viz.*, at Newara, at Bejwari, and repairs to the old bund at Sirsena ; and whatever can be done to meet the wants of the villagers of Nadbai. The project for this much-desired extension to be prepared without delay, the canal to be widened as required, the spoil bank to be on one side only.

(4.) *Helana Canal* (Para 7).—At present a large part of the discharge flows over the fields without sufficiently saturating the soil. More subsidiary reservoirs are required.

A new cross bund at Beri and another near Pahessar. The diversion of the flood discharge towards Helak, the aim being to spread the river floods over the dry tracts northward. (Para 7).

(5.) *The Lalpur Canal.*—No improvement required at present. The Lalpur Bund requires new distributaries.

One of the subsidiary bunds (the Ajronda Bund) to be restored. (Para 8).

(6.) *The Oochain Canal.*—The bund at Sewar to be raised and strengthened so as to make it secure against a breach.

A channel to be cut from Marwara, the present extremity of the Sewar Bund, to the Moti Jhil Bund. The project for this is now being prepared (March 1904). A new shallow reservoir to be formed across the course of this channel by a new bund between Marwara and Akhad.

(7.) The flooding of any large areas near the city should be carried out in consultation with the Medical authorities.

(8.) Attention is especially invited to the possibilities of increased Irrigation from the Gambhir River. Whether it may not be possible to make a storage reservoir, somewhere on its course through the Bharatpur State, or by a cut from it to some natural or artificial basin, if so or on some of its tributaries. Whether such a project would be advisable. (See Appendix C).

(9.) To partially restore the flow of the Gambhir to its old course by cutting a channel through the new deposit of silt that bars its former course, so that the Dhanagaon and Bokhol cuts which feed an extensive reservoir system may receive the proper supply, near Khanwa, on which they depend.

This, it is believed, would help to moderate the flood towards the Ajan Bund. (Para 17). This is being now carried out (March 1904.)

(10.) *The Pichuna Canal.*—Head regulator fixed last year to afford control of the flood water, the channel to be widened to reduce the velocity, the earth so got to be put on the right bank to raise and strengthen it : the cut to be continued up to Pichuna to satisfy the villagers, who are said to have suffered considerable loss since the Banganga shifted its course towards Oochain, much of the land in Pichuna and the adjoining villages having gone out of cultivation.

A few bridges and a fall may be rquired. A supplementary project should be prepared for doing whatever is necessary (Para. 15). These works were partly done last year (1903), and work is still going on.

(11.) *The Ajan Bund.*—The bank has been raised and strengthened, the escapes have been increased and sluices provided to give a better margin for the retention of heavy floods, to enable the supply to be adequately controlled, and to prevent the danger and possibility of a high flood re-occurring. Efforts should be made to utilize the flood water of the Gambhir more fully. It might even be possible to extend Irrigation beyond the Ajan Bund eastward into the British territory if water is available and is desired. The Chiksana Bund is proposed now in Appendix B, and this might help to give a better return on any expenditure which might be incurred by Bharatpur. (Para. 16). The proposal to divide the long length of the bund into compartments is often adopted in such cases, and has advantages. The dividing bunds afford means of crossing the water instead of having to go round one end or the other, a consideration when the main bund is of great length.

(12.) *Bareta Bund.*—The protection of the escape to prevent cutting back, an urgent work (Para. 19), was completed last year (1903).

(13.) The importance of keeping up in a thoroughly efficient state the many small bunds scattered over the country, upon which the prosperity of so many villages depend, especially to see that the escapes are sufficient. This is a point on which bunds constructed by natives often fail. (Para. 20). This is being done.

(14.) Those bunds which have not yet been taken up should be repaired as soon as possible. See Mr. Devenish's Report and suggestions on each. (Para. 21). It is unnecessary to repeat these here, as the work is being done.

(15.) The investigation and selection of good sites in the southern portion of the State, where local drainage may be stored, all the small streams for instance which drain into the River Gambhir. In Para. 22 Mr. Devenish gives names of sites where he recommends new works should be carried out. All he says is deserving of attention.

19. Regarding the water supply for the city of Bharatpur, Mr. Devenish (the late State Engineer) suggested, in his note, dated 6th February 1903, that although it does not pertain strictly to Irrigation, the authorities of the Bharatpur State would do well to obtain advice on this subject from Sir Swinton Jacob during his visit.

He stated that the whole discussion which has taken place on the subject hitherto, is recorded in the Public Works Department Office in Bharatpur.

Briefly, the only proposal which seems to have been generally approved, is for a supply from the Bareta Bund, and the chief objection he states to this proposal is the very large outlay that would be required to bring the water from a distance of about 25 miles.

The water would be brought by a duct to Sewar, and would then have to be filtered and pumped into an elevated cistern commanding the city.

The Consulting Engineer also received a letter from the Agency Surgeon, Major H. E. Drake-Brockman, on the subject. This and other papers bearing on the subject will be found in Appendix G. The importance of the question makes it advisable to omit nothing which bears on the subject.

No one reading these papers can fail to be impressed with the necessity of something being done to prevent the flooding of the land near the city, and of the urgent need of a better supply of good drinking water.

The Consulting Engineer has prepared a Note on the subject (see Appendix G). The subject is a very important one, and requires to be dealt with by an expert after exhaustive enquiry. Considering the short time he has been able to devote to the matter, the Consulting Engineer feels all he can do at present is to make suggestions.

S. S. JACOB, Col.,

Consulting Engineer for Irrigation in Rajputana.

March 1904.

APPENDIX A.

Improvement and Extension of Irrigation in the Bharatpur State, Rajputana.

Colonel Sir Swinton Jacob, Consulting Engineer of Irrigation in Rajputana, having requested me to place on record a Note regarding the possibilities of the future improvement and extension of Irrigation in the Bharatpur State, Rajputana, I have prepared the attached Memorandum. I have the honor to submit it for the disposal of the Consulting Engineer for Irrigation in Native States.

J. A. DEVENISH,
Executive Engineer, P. W. D.

APPENDIX A.

Note on the future requirements and possibilities of Irrigation in the Bharatpur State.

Introductory.

1. The Irrigation system of the State has been described in a printed record, which contains the names and particulars of all the existing bunds and canals, together with a statement of areas irrigated by each up to the Rabi harvest, 1901-02 A.D. Complete maps, showing the position of existing works and the areas flooded, are available in the P. W. D. Office at Bharatpur.

Area Irrigated during the rainy season of 1902.

2. The preliminary measurements made during the rainy season of 1902 show that about 95,000 acres of culturable land were then flooded. It is probable that about 80,000 acres of this flooded land will be cultivated.

The measurements may be conveniently divided into the following groups :—

	Acres.
Land flooded by the Banganga and Gambhir Rivers ...	60,000
Land irrigated by the Sikri Bund, and subsidiary works from the Ruparel River	18,000
Land commanded and irrigable from the Bareta Storage Reservior	8,000
Land irrigated from small local catchments	9,200
Total acres about	95,200

anganga and Gambhir floods.

3. These figures show at a glance that the greater part of this irrigation is derived from the Banganga and Gambhir floods. It will be best to consider the distribution of the floods from these two rivers separately, as they now flow mostly in separate courses.

The normal flood supply from the Banganga can be fully utilized, but that from the Gambhir River is in excess of probable requirements.

Improvement of works pending on the Banganga River r a supply.

4. The inundation canals or cuts taken out of the Banganga River are in their order of position as follows :—

Ooloopura Canal, left bank.
Pathena Canal, right bank.
Halena Canal, right bank.
Lalpur Canal, left bank.
Oochen Canal, including the various spill channels feeding it, right bank.

There is no room nor necessity for making any more new cuts from the Banganga River, but those already made should be improved, principally by extending them in length, and by constructing low banks to form shallow reservoirs in which the flood supply can be retained over the fields.

Ooloopura Canal.

5. Referring to each separate canal in order, the Ooloopura Canal is the first of the series. This is an old work that has been partly improved, but without success.

The head of it is badly placed and the head reach is too narrow, consequently it becomes silted up by every flood. This is the only canal which has failed in this way.

To improve it a new mouth should be cut further up stream; the canal should be widened from 20ft. to 35ft. at least, and the bed lowered, falls being put in where required. The canal would then serve to fill the large Ataripura Bund which now remains unfilled, and it would flood several hundred acres of land on the way. But seeing that this canal has not hitherto been remunerative, and that the supply in the rivers often falls short of the quantity required to serve the other canals lower down, it would be prudent not to spend capital on it until all the other canals have been improved to their full capacity.

The Pathena Canal.

6. The Pathena Canal is new. The bed width is only 30ft., the length is about 2 miles. Before widening this canal the benefit to the land already traversed should be ascertained.

The cultivators, now that they feel secure of a supply from this canal, are apt to disparage the benefit, while, owing to the recency of its construction, a fair judgment of its possibilities has not yet been gained, but the results apparently justify an extension of the canal by lengthening it, so as to command a large area. There is an abundance of barren land to be irrigated. Before anything else is done the present canal should be trimmed up to section, and subsidiary shallow reserviors to hold up its discharge should be formed in suitable places, *viz.*, by a bund at Newara, another at Bejwari, and by the repairs of an old bund at Sirsena. The inhabitants of Nadbai and the neighbourhood are clamorous to have an extension of the canal to flood their sandy fields. The fall of the country is favourable, and there are no difficulties in the way of acquiring the land for construction.

A project for this much-desired extension might be prepared as soon as possible. The canal could be widened by degrees according to demand, the spoil bank being on one side only.

No head works for the Pathena Canal are necessary. Head regulators to these inundation canals * are costly, and they often act merely as useless obstructions. Should the unlikely need ever occur of closing the canal, it could easily be closed by a temporary earthen dam, or by planking up a bridge crossing it.

Halena Canal.

7. The Halena Canal has been in use for some four years, during which time the results obtained from it have generally been considered very satisfactory. A considerable area of Kharif crop has been flooded beneficially in addition to the land rendered culturable for the Rabi, but as the control over the floods discharged is deficient, it is possible that in some years Kharif crops may be damaged by the inundations. The

* This is the case more in respect to the Banganga floods than to those of the Gambhir, owing to the difficult character of the banks.

bed width of 50 ft. is sufficient. What is chiefly required to improve the canal is an extension of the system of subsidiary reservoirs, as at present a large part of the discharge flows over the fields without saturating them deeply enough to render them culturable for the winter crop should the rainy season terminate early, for the land becomes hard on the surface at sowing time unless the rains have continued till September or unless water is held up over the fields by banks.

A new cross bund is required at Beri and another near Pahersar. The Halena-Bharatpur road has been made to act as a training bank, with cross spurs at intervals as far as Pahersar.

The flood discharge should be diverted thence towards Helak, a very thirsty district. The greatest slope of the country is towards the Bharatpur city, but the aim should be to spread the river floods northwards over the dry tracts.

The Lalpur Canal.

8. The Lalpur Canal, 50 ft. bed width, has hitherto proved very satisfactory. It feeds the large Lalpur Bund, from whence distribution is made to other subsidiary reservoirs.

The canal requires no improvement at present, but the Lalpur Bund requires new distributaries to be made from its sluices. There is a considerable area of waste land that might be thus reclaimed. One of the subsidiary bunds, the Ajronda Bund, remains to be restored.

Oochain Canal.

9. The Oochain Canal is a continuation of a spill channel that runs parallel and close to the Biana-Oochain Road, the river some 12 years ago having voluntarily adopted the ditch of the road as a guide to its course. Other spill channels impinge on the road at intervals.

The Biana-Oochain Road is now embanked for use as a training bank, with flood regulators at intervals, so that the whole volume of the river is either diverted along it to feed the Oochain Canal or is released by the regulators across the road. The quantity so released is impounded by the Nekpur Bund, and no part of the flood runs to waste.

There is very little improvement of this system required.

The flood entering the Oochain Canal is distributed by means of the embanked Oochain-Sewar Road in a similar manner, with cross spurs on the upstream side of the road to spread the flood out, and with subsidiary reservoirs or bunds in suitable places on the other side to catch the surplus quantity released by the sluices.

A large portion of the discharge of the canal (now 50 ft. bed width) ultimately reaches Sewar.

Here there is a very large terminal "bund" or embankment, which flanks and protects the Sewar town. The Sewar Bund has been largely extended during recent years so as to bring additional areas under command.

The local system of bund, although somewhat complicated to describe, is simple to comprehend after inspection of the locality with a map.

To improve it the Sewar Bund should be raised and strengthened, so as to make it secure against the risk of a breach.

A channel might also be constructed leading from Marwara, the present extremity of the Sewar Bund, to the Moti Jhil Bund, and another shallow reservoir might be formed across the course of this channel by means of a new bund between Marwara and Akhad.

Agricultural value of the inundation near Sewar and Bharatpur.

10. The inundation of the land in the neighbourhood of Sewar, 4 miles from Bharatpur, has produced a great change in the agricultural condition, the land formerly rented at one rupee per acre being now rentable at eight rupees per acre.

The objection to flooding on the score of sanitation.

11. But the flooding of large areas is generally considered to be injurious to the public health, as indeed all forms of Irrigation are in a more or less degree.

The question therefore should be weighed, whether it is justifiable or not to add any more to the flooded area that now almost completely encircles the Bharatpur city. As far as the villagers are concerned there is no doubt that they would prefer to get the water at the cost of some additional sickness than for their land to lie fallow when it might be flooded, and afterwards cropped.

If the flooding is not very extensive, and if the land dries and is ploughed soon after the rainy season, it is possible that the flooding does no more harm to health than the rainfall itself does without it, for it is the general experience that the flooded and the dry villages suffer equally or nearly equally from fever, the reason probably being that the insanitary condition of both is so extreme that the flooding makes no perceptible difference.

Since it is now established that malaria is propagated by mosquitoes bred chiefly in small pools, the unhealthiness of a village or town may be due to the insanitary excavations in its midst rather than to widespread flooding on its outskirts.

Flooding in the neighbourhood of the Bharatpur city.

12. In the Bharatpur State, as far as the villages are concerned, the great access of prosperity brought by inundating their land, overcomes any objection on the score of possible deterioration of health that may be made against it, but in the case of the Bharatpur city it is necessary to confine the flooding within certain limits, because, although it may be the case that the proximity within a radius of a mile or so of large sheets of water makes no difference to the health of the city, which contains in its midst almost unchecked all the elements of disease, nevertheless the health of the city is, and always has been, so bad that any cause that may be supposed to add to it should be as far as possible eliminated. The medical authorities should be asked to define a radius outside the city walls within which flooding should be avoided.

The need of a fresh water supply for the city.

13. Cognate to this question is the need for a fresh-water supply for the city, on which subject a separate Memorandum is attached.

Absorption of the Banganga and change of the course of the Gambhir River.

14. The Banganga River in a year of normal floods can be entirely absorbed within the State. Until recent years the Ajan Bund, which forms a sheet of water 14 square miles in area, was supplied from this river, but within the last four years the Gambhir River has shown an increasing tendency to spill in the direction of this bund, while at the same time the Banganga River floods have been so moderate in volume that they have mostly been absorbed before reaching it. In 1902 the Gambhir River finally left its usual channel, and it has now selected a course leading directly into the basin of the bund.

This important change is not altogether beneficial, but it can be, and has been, utilized by letting the Ajan Bund be filled by the Gambhir River only, the Banganga floods being thus free for distribution in other directions.

The Ajan Bund may therefore be now considered as a part of the Gambhir River Irrigation system.

The Gambhir River.

15. This river has a catchment area of about 1,000 sq. miles, the greater part of which is rocky, whereas the catchment of the Banganga River is mostly sandy.

This fact causes an immense difference in the relative discharges. The run-off in the former may be as high as 75 per cent. and in the latter as low as 5 per cent. and the normal flood of the Gambhir very largely exceeds that of the Banganga River, which has a larger catchment.

Before the utilization of the Banganga spill floods they were amalgamated with those of the Gambhir River, as figured in the Ordnance Map of 1867. Hence the combined floods were always known as those of the Banganga River, the name given to the combined stream.

It is important to differentiate this matter, as there is a strong probability of the floods of these two rivers being in future utilized separately.

The Gambhir River enters the Bharatpur State through a narrow valley or pass amidst rocky hills near Biana, along which valley lay the historic route from the Moghal Capitals to Rajputana and the Deccan.

The stream is too large and the valley too wide for a dam to be constructed, except at prohibitive cost, and a work of this kind, moreover, appears to be unnecessary, as most of the land that would be commanded is already traversed by natural spills.

There is, however, in this stream an immense potentiality, which may be left for the Consulting Engineer of Irrigation in Native States to consider.

It is possible that if the tributaries of the stream were impounded in Karauli and Jaipur that the flood discharge entering the Bharatpur State might be reduced to more manageable volumes, but it is very unlikely that it would at any time be remunerative to the Bharatpur State to construct a dam and weir in the Gambhir valley.

This discharge can, however, be utilized abundantly by means of inundation canals taken out from the river bed after it has debouched from the hills.

The following are the existing works dependant in the Gambhir River floods in their order of position :—

(1) The Pichuna or Seola Canal on the left bank.
(2) The Ajan Bund on the left bank.
(3) The Dhana Cut on the right bank.
(4) The Ghata Canal „ „
(5) The Bokholi Canal „ „
(6) The Shekhpur and other small channels.

The so-called Pichuna Canal is taken out from the Gambhir River near the village Seola, the object of it being to flood the Pichuna district when required, and if necessary to feed the Ajan Bund. The Pichuna Canal.

The cut was opened last year (August 1902) for the first time, but the work required to make it permanent is not yet completed. The head of it being well placed in deep cutting, two or three chains long, through hard rock is secure, and affords facility for control by means of a head regulator, which should be built as soon as possible across the bed of the cut at its mouth. The supply is also abundant and secure, for the Gambhir does not begin to shift its course till it has turned the end of the outlying rocky spur on the left bank where the cut is situated. By means of the proposed regulator, the flood could be let into the cut when desired, in such volume as not to scour out the channel in soft soil, or it could be shut out altogether when flooding was not required.*

During the last year's floods, owing to the want of such means of control, a large volume of water suddenly entering the new canal damaged the earthwork. The channel might also be widened to reduce the velocity, the earth got from the widening being used to raise and strengthen the right bank on the down stream side. This bank has to withstand the pressure of as much as 10 ft. of water, and while this depth of water lasts a large area of land is submerged beneficially on the opposite unembanked side of the channel. The cut discharges into an old spill channel of the Banganga River that leads ultimately into the basin of the Ajan Bund. By this means an annual supply to this important reservoir can always be ensured. A continuation of the cut has been projected to lead up to Pichuna, where the villagers are very anxious to have a renewal of the flooding of their land that occurred formerly, before the Banganga River shifted its course towards Oochain.

Since the diversion of this river much of the land in Pichuna and the adjoining villages has gone out of cultivation, and there has been a considerable loss of prosperity.

The loss of the flooding has not been the only cause of the deterioration of agriculture in that locality, for the alteration of the course of the Banganga River was preceded by a deposit of sand over the fields, which

* Regulator fixed and repairs and improvemants carried out last year (1903), and extension going on now (March 1904.)

are now covered with long grass and "jhao." The flooding of this land would now reclaim it from the waste. Not only the earthwork and regulator mentioned but also a few bridges and a fall may be found necessary for the Pichuna cut, so that what is first required is a supplementary project for the completion of it.

Improvement of the Ajan Bund.

16. The works advisable for the improvement of the Ajan Bund are so much more easily rendered intelligible by an inspection of the locality than they can be by description, that it hardly seems within the scope of this memorandum to enter into details regarding them, especially considering the intended visit of Sir Swinton Jacob to Bharatpur.

Briefly, the case is that the supply to the bund is now apt to be excessive. What is most needed is a slight raising and strengthening of the bank to give a margin of safety for the retention of heavy floods, pending the discharge of the surplus volume, this raising of the embankment being accompanied at the same time by a limiting of the supply to the basin, in order to prevent the possibility of a dangerous high flood level occurring within it again.*

The chief source of supply is now the current of the Gambhir River, which, having left its old course, spreads itself out over the left bank and adopts some of the old Banganga River spill channels, flowing past Bhensa Berauli, and afterwards impinging upon the southern extremity of the bund at Sikhroda, or passing through breaches in it towards Fatehpur Sikri.

In August 1902 a heavy flood from the Gambhir River occurring while the basin of the bund was full, proved too much for the discharging capacity of the weirs and sluices, while, owing to the restoration of the southern limb of the bund, there was no other opening for the passage of the flood, all the old breaches being closed. Consequently the level of the water impounded rose till the bank was topped and breached at two places, one about two miles from Sewar, and the other near the opposite extremity of the bund, some 8 or 9 miles distant.

The former breach has been closed, but the latter has been kept open to relieve the pressure of future floods until some better means of escape can be provided.†

The weir at Kalyanpur has been injured and some of the sluices have been slightly damaged. An ample supply for requirements can be retained at a safe flood level, provided that the surplus floods be allowed to escape through breaches or openings in the southern extremity of the bund where they first impinge on it, but if it should at any time be desired to utilize the floods more fully, the influence of the bund can be extended‡ by constructing the necessary works for holding more water. There is, however, no demand to warrant a large expenditure for this purpose.

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* Improvements carried out.

† All done and escapes provided.

‡ The means recommended for extending the area, at the same time adding to the security of the work, consist partly in a division of the waterspread into compartments.

17. If, as it appears, the Gambhir River has deserted its old course almost entirely, there will be considerable loss of prosperity on the right bank of the river in the Rupbas district to be anticipated or averted; and the only means of averting this loss will then be to partially restore the flow of the river in its old course by artificial means, chiefly by cutting a channel through the new deposit of silt that bars its former course; for the Dhanagaon and Bokholi cuts which feed an extensive reservoir system depend on the existence of the river current near Khanwa.*

The partial restoration of the Gambhir to its old course.

It would probably not be very expensive to make a sufficient opening through the sandy bar, and this measure would at the same time moderate the floods flowing towards the Ajan Bund.

18. The floods of the Ruparel were much below the normal. In a year of good floods the area irrigated thereby should amount to 40,000 acres or more.

The Ruparel Irrigation System.

There are no considerable works necessary for the extension and improvement of the Ruparel system, the case here being that the supply has frequently been found deficient to feed the works existing.

19. The Bareta Bund has been a very successful work of its kind, and the value of it is higher than the figures of acreage would imply comparatively, because the irrigation from the storage reservoir is of a less crude quality than that of the rainy season flooding, water being supplied from the reservoir to the fields only according to demand and throughout the year.

The Bareta Bund.

This large work requires some minor improvements, especially the protection of its escape channel, which is threatened by cutting back.

A tail fall to the escape channel is urgently needed. It has been deferred hitherto only to economise capital expenditure, but the annual income of water from the catchment has shown the probability of the escape coming into action in a year of heavy storms, and the protection of the escape channel should be no longer deferred. No new ducts are required. The extension of the area benefited will depend mainly on the judicious administration of the supply.

20. The least important source of Irrigation in respect of magnitude is the impounding of small local catchments. These are not likely to often yield much more than 10,000 acres of irrigated crop annually, when the results of all are added together. But considering the value of such works in detail, it will be found that they comprise about 150 different bunds scattered about the hilly districts.

Small local catchments.

Each effective bund is looked upon by the villagers in whose land it is situated as their most treasured asset, because it protects the best land in the village, prevents the local drainage from running to waste, keeps up the well level, and provides water for the cattle.

*Is now being carried out, March 1904.

In the Bharatpur State most of the local catchments have already been impounded. There are a few places where small ruined works can be utilized, and there still remain a few good sites for new bunds to conserve local drainage, chiefly in the sparsely inhabited ravine tracts (or Dhang) of the southern extremity of the State. All the small streams draining into the Gambhir Valley on both banks might be dammed. But before any new schemes of this nature are taken in hand the old works should, wherever possible, be rendered fully effective.

21. Nearly all the bunds have now been restored and improved.

The following are a few remaining in a ruined or imperfect condition that claim early attention :—

The Kani, Qundi and Jaisora Bunds.

Restoration and improvement of old works.

These bunds are placed together in one line across small drainage courses aggregating about 4 or 5 sq. miles of catchment in the "Dhang," between Bangarra and Bajna. Part of the restoration work has been done recently ; the part remaining should, if possible, be completed before the next rains. The villagers are poor, and the work would be a great help to them, adding perhaps 400 or 500 acres of crop to their harvest. (*a*)

Restoration of the Shergarh Bund, near Biana.

The catchment is small, but the work is worth doing Area to be gained about 100 acres. Probable cost about Rs. 6,000. (*b*)

Improvement of the Soohans Bund.

A small bund in the Weir district that might be improved. Area to be gained about 50 acres.

Improvement of the Bhagora Bunds.

These are small bunds in the Weir district. Area to be gained about 100 acres or more.

Restoration of the Baisora Bund.

The Baisora Bund close by the Jaisora Bund has been restored recently, but the work probably requires some additions. Area to be gained 50 to 100 acres. (*c*)

Improvement of the Tharko Bund (between Weir and Biana).

Area to be gained about 50 acres.

Restoration of the Bidhiari Bund, near Biana.

This is a small bund worth restoring, because it can now be supplied by a feeder channel from another catchment. Area to be gained about 100 acres. (*d*)

(*a*) Being carried out this year, 1904.

(*b*) Do. do.

(*c*) Do. do.

(*d*) For next year.

Restoration of the Khan Sujanpur Bund.

Khan Sujanpur is a very poor village near Rupbas. Area to be gained 50 to 100 acres.

Improvement of the Papra Bund.

The Papra Bund near Gopalgarh is in the north of the State. This is a large effective bund, with a catchment of 4 sq. miles. The bund is too low and the best is not made of the supply, the sluices being opened when a heavy flood comes. By raising the dam and at the same time adding another escape passage some 200 acres or more might be gained at an outlay of about Rs. 5,000.

This work should be done as soon as possible.

22. Some places where new bunds are to be recommended are as follow:— Proposed new Bunds.

New Bunds proposed at Nagla Seo Lal and Dehgaon.

These bunds would be subsidiary to the Khatnawli Bund (Biana Tehsil) recently restored, which has a more than sufficient catchment of 12 sq. miles.

100 or more acres might be gained in each place at a moderate cost. The supply is ample and the land good.

New Channel required from the Rincholi Bund (between Oochain and Biana).

The Rincholi Bund has an excessive supply which might be utilized by leading its escape channel into the basin of the Nekpur Bund.

New Channel proposed from the Kaml Hoz Bund at Biana.

The Kaml Hoz Bund recently constructed has an excessive supply from a rocky catchment of 4 or 5 sq. miles, the bund having been designed chiefly to divert the stream into the basins of neighbouring bunds. By means of a new channel a contiguous area of 300 acres or more might be commanded at a moderate cost. Mr. Allah Bux, Overseer at Biana, knows the details of this scheme. (*a*)

Proposed new Bund at Purwa, near Bangarra.

There is an excellent place for a bund here, which would be a great help to the poor and isolated villagers of the neighbourhood (in the Dhang). The stream has a free catchment of some 10 sq. miles, and water is badly needed there in the dry months. Area to be gained about 400 acres.

This is a promising scheme, which should be prepared in detail as soon as possible. (*b*)

(*a*) Being carried out this year, 1904.
(*b*) Do. do.

Proposed new Bund across the Gadha Khar, near Talehti Biana.

There is an excellent site for a dam here across a hill stream with a small rocky catchment. (*a*)

Raseri Nulla.

The Raseri Nulla on the right bank of the Gambhir River now runs to waste. The villagers of Jarwar are anxious to have an old bund across a tributary of it restored.

This stream is one of those that might be impounded when funds are available.

Khair Nulla and Khareri Bagren Nulla.

The Khair Nulla and Khareri Bagren Nulla is in the Dhang, east of the Gambhir, near Biana. These might be prospected for sites for new dams, as the streams have good catchments and run to waste through a very poor district.

Proposed new Bunds near Ballabgarh.

There are a few sites available for small bunds in the Ballabgarh neighbourhood, which have been noted in the famine relief works' programme.

Proposed channels from the Agra Canal to enter the Bharatpur territory.

23. Lastly there remains to be mentioned a proposed new escape channel from a distributary of the Agra Canal to enter the State at its northern extremity.

This project, proposed originally in the interest of the Agra Canal, is likely to be beneficial, if it is carried out, to a small area in the Kama Pergannah. (*b*)

There are also remote possibilities of the extension of the Agra Canal Irrigation into Bharatpur State across its western border, but it is very improbable that the Government of the United Provinces will be able to spare the water on any terms.

There are no great engineering difficulties in the way of crossing the border near Kama and Dig, and the objections are merely administrative; but to bring a channel from the Agra Canal to the Bharatpur city taken out from Chota Kosi, and thence led along the Muttra-Bharatpur Road, a difficult depression would have to be crossed. (*c*)

As for the outlaying estates belonging to Bharatpur, situated within the Muttra district, every effort ought to be made to get a supply to them from the adjoining Agra Canal distributaries.

(*a*) Now being constructed.

(*b*) Postponed owing to the difficulties in connection with collection of water rates.

(*c*) Too expensive owing to difficult depression.

This would add greatly to their value. If this is not possible the estates should be sold at fair value, taking into account the facility of irrigation not afforded to foreign territory, but freely available if the estates were incorporated in the surrounding British district.

24. In concluding the Memorandum, attention may be drawn to the importance of preserving the existing Irrigation Works of the State in good order, for which purpose an ample establishment and a fair allotment of funds for maintenance and repairs will always be necessary.

Importance of preserving existing works.

J. A. DEVENISH,

6th February 1903. *Executive Engineer, P. W. D.*

Note Regarding Supply of Drinking Water to the City.

The question of a drinking water-supply for the Bharatpur city does not pertain strictly to irrigation, but the authorities of the Bharatpur State would do well to obtain the favour of advice on the subject from Sir Swinton Jacob during his visit.

The whole discussion that has taken place on the subject hitherto, is contained in one file in the P. W. D. Office at Bharatpur.

Briefly, the only proposal approved generally has been for a supply from the Bareta Bund, and the chief objection to this proposal is the very large outlay that would be required to bring the water from a distance of 25 miles.

A gravitation channel to Sewar, where the water would be filtered and pumped into an elevated cistern commanding the city, is the main part of this scheme. The channel could be formed economically from local materials instead of using pipes.

J. A. DEVENISH,

6th February 1903. *Executive Engineer, P. W. D.*

APPENDIX B.

A Note on the use of shallow reservoirs for temporary storage of flood water, by Mr. J. A. Devenish, Executive Engineer, Public Works Department.

In a flat country where sites for deep reservoirs are not obtainable, water may be stored temporarily for Irrigation by the use of shallow basins formed by low banks built across wide drainage depressions. The drainage of these depressions and floods diverted from other catchment areas discharge into the basins (locally termed "bunds"), and are impounded in them to their full capacity of each, the surplus quantity received being allowed to escape by sluices or by bye-washes into subsidiary basins; or, if these latter are not available, the escaped water can be diverted to saturate the neighbouring land where required. In a typical case, supposing that the longitudinal slope of the bed of a drainage depression averages 8 ft. in a mile, and that the width of it across is one mile, a bank one mile long stretching across the dip and sufficiently high to retain an eight (8) ft. depth of water is capable of submerging about half a square mile of country in front of it, and the basin, if it can be filled, is capable of retaining about 100 million c.ft. of water, more or less, according to its contour. With a rainfall of 30 inches, between five and ten square miles of catchment area would be required to shed enough water to fill it.

Such a basin is by no means adapted to the prolonged storage of water, but under favourable conditions of climate and soil it may be of great benefit to agriculture when used for the temporary storage and distribution of floods. The loss of depth of retained water due to evaporation and percolation and absorption in the basin is not less than 8 * ft. per annum, and it is economical to empty the basin as soon as possible by means of sluices in order to flood land in rear. If the floods have been late and if the supply is ample, the basins may be nearly full at the end of the rainy season, when the time comes to prepare the ground for the winter crop; if there have been no late floods the basin may be nearly empty at that time. As soon as the ground surface of the bed becomes dry, either by natural exhaustion of the reservoir or by the emptying of its contents through sluice openings, the land that has been submerged in front of the bank will be found thoroughly saturated, softened and fertilized, so that it is at once ready for the plough. The land that has been flooded in rear of the bank by means of sluices and distributary channels will also be softened for the plough and saturated sufficiently for the sowing of the Rabi.

It is important to note that the land in the bed of the tank or basin is far more valuable than that in rear, because not only has the sub-soil of the former been saturated, to which the roots of the crop penetrate, but also a layer of fine silt has been deposited on the surface; whereas the Irrigation in rear does not saturate the sub-soil or deposit much silt.

The crop sown in the bed of the tank is independent of subsequent watering in order to reach maturity. Moderate rain, indeed, assists the

* Up to 15 ft. per annum in a recorded case.

growth and increases the yield, and in years when the winter rains fail, the growing crop is in some places watered from wells. Without such aid, however, it will remain healthy, deriving its nourishment from the moisture retained in the sub-soil.

The crop sown in the rear of the bank depends partly on a subsequent refreshment by winter rain or from wells. Failing such assistance its yield is small.

The system of shallow reservoirs here described, is suitable not only for the impounding of small local catchments, but also for the distribution of floods from large streams, which may be diverted or led into the basins by means of feeder channels.

If the latter source of supply be available, sluices are used to carry off the excess supply above the capacity of the reservoir, distributary channels from the sluices discharging into other basins or saturating the fields in rear. Under suitable conditions the main advantages of this system of shallow basins compared with deep storage reservoirs are :—

(1) They are far more remunerative. The cost of construction is very much less. For low pressure of water, earthen banks of slight section are sufficient. The use of masonry works is reduced to a minimum. The work is easy to design and construct.

(2) Dealing with low pressures the risk of damage is much less, and damage is easily repairable if it occurs.

(3) A much greater area of crop is obtained in proportion to the supply of water, owing to the comparatively wide water-spread, in proportion to the cubic capacity.

(4) The bed of the tank is fully utilized for agriculture, and becomes a much valued asset of the village, instead of compensation being paid for the loss of the land to the villagers.

(5) So much water is not exhausted unproductively by evaporation and absorption during prolonged storage as in deep reservoirs.

(6) The larger part of the crop is more valuable owing to the fully cultivated bed being fertilized by silt, whereas in deep reservoirs bed cultivation is usually discouraged and the silt deposit is consequently wasted. Crops irrigated by ducts during growth do not attain the yield of the bed crops. Even in years when the bed is not flooded it is cultivated, the enrichment of the soil being permanent.

J. A. DEVENISH,

Executive Engineer, P. W. D.

APPENDIX C.

REGARDING THE CHIKSANA BUND PROJECT.

The State Engineer, Mr. Judd, describes the project thus: "As during high floods a large quantity of water escapes from the Ajan Bund and passes into British territory, and as the full flood of the Gambhir River is beyond the retaining capacity of the Ajan Bund, it is proposed to construct a new bund near the Chiksana village, which is about 9 miles from Bharatpur, to catch the water thus wasted.

This will impound the flood, and land above 5.200 bighas will be under irrigation.

The proposed bund will be 11 chains long, with a weir 300 ft. long on its north end.

As the soil at the site is sandy and will percolate water, a pucca core-wall has been provided in the estimate.

The earthen bund is proposed 12 ft. wide at the top, with 3 to 1 and 2 to 1 slope inside and outside respectively.

The weir is proposed 300 ft. long with a 3 ft. head flowing over it, giving a discharge of 5,550 c. ft. of water per second.

As there will be an inside irrigation of about 5,250 bighas and outside irrigation of about 250 bighas, the total 5,500 bighas—it will increase the State revenue to Rs. 5,000 per annum or 33 per cent. of the estimated cost of the work, as detailed below:—

5,500 bighas at Re. 1	giving	Rs.	5,500
Deduct for maintenance	„		500
Net revenue to the State ...		Rs.	5,000
The estimated amount is	„		15,628

The average rainfall is 25 inches. The capacity of the tank 300 million cubic feet. The catchment area below the Ajan Bund 40 square miles. The direct discharge from the Ajan Bund 8,400 cusecs."

I visited the site with the State Engineer, Mr. C. R. Judd, on the 10th March 1904.

In the course of conversation with some villagers of Chiksana, who accompanied us, it appeared that some of them did not wish this bund made, as they stated it would submerge some of their fields close by. Considering that a Revenue Official had accompanied Mr. Judd when he came to see the place to make enquiries, it seems strange that any objection of this sort should be made now. It is well, however, that every objection should be carefully considered before work is begun, so they were told to submit a petition, stating all they had to represent, and it would be forwarded to the proper quarter for investigation.

This is a matter which should be settled before expenditure is incurred.

2. The villagers were asked if there was any site for a bund which would suit them better. They mentioned one near a peepul tree, a few hundred yards higher up, which we inspected. Their fields would then be below.

Although no sections have been taken, it was clear a much larger bund would be required on this line.

It would be easy to have a section taken and an estimate prepared for a bund on this line.

If the Revenue Department considers that there is good reason for objections made by the villagers, I would suggest this alternative estimate being prepared.

It will be easy then to decide which line to adopt.

3. If any compensation is necessary on account of wells or anything else, it might be noted on the estimate.

4. The soil is well adapted for an earthen bund. I do not consider any masonry core-wall is necessary.

A good trench should be dug along the centre line of the bund after removing all course grass and scrub, and the trench be refilled with new materials, so as to ensure good connection between the bund and the solid ground.

5. The sluice for emptying the tank is to be of masonry; there should be masonry core-walls extending for about 15 feet on each side to prevent any creep of water along the masonry of the sluice tunnel. The masonry should be left quite rough, not plastered.

6. In this soil 3 to 1 for the inner slope will not be enough unless it is covered with grass, or protected by broken stone or kunkur to break the force of the wave action.

7. It is not a suitable place to have an escape at the north end on this soil; even if made of masonry, as proposed, there is sure to be a tendency to cut back below the weir, and if an escape is put here it will require a large quantity of dry stone placed in the ground beyond the flooring. If it can be arranged, a better plan in my opinion would be, to make the bund say 2 or 3 ft. higher, and to let any surplus water flow over the natural surface of the ground between the villages of Mendah and Dhemartola in the direction of Fatehpur Sikri.

This would save the expense of any masonry weir, or of any bund along this line, as noted in the tracing, and at the same time would increase the capacity of the tank.

8. As regards the canal to guide the overflow from the Ajan Bund this has not apparently been surveyed or arranged for yet.

I would suggest it should be so arranged if possible more or less on a contour line, so as to retain water in pockets along the general line, allowing the water from the northern end, after all had been filled, to pass off into the watercourse to the proposed bund at Chiksana.

9. I am doubtful if the profits will be so large as is expected, but the site is a good one, and if the expense of a masonry weir and core-wall can be saved, as suggested, the cost will be very much reduced, and the returns ought to be good.

S. S. JACOB, COL.,
Consulting Engineer for Irrigation in Rajputana.

APPENDIX D.

REGARDING THE GAMBHIR RIVER PROJECT.

Mr. Devenish, the late State Engineer, remarks as follows :—

"The Gambhir enters the Bharatpur State through a narrow valley amidst rocky hills near Biana, along which valley lay the historic route from the Moghal capitals to Rajputana and the Deccan.

The stream is too large and the valley too wide for a dam to be constructed, except at prohibitive cost, and a work of this kind, moreover, appears to be unnecessary, as most of the land that would be commanded is already traversed by natural spills.

There is, however, in this stream an immense potentiality, which may be left for the Consulting Engineer for Irrigation in Native States to consider.

It is possible that if the tributaries of the stream were impounded in Karauli and Jaipur, that the flood discharge entering the Bharatpur State might be reduced to more manageable volumes, but it is very unlikely that it would at any time be remunerative to the Bharatpur State to construct a dam and weir in the Gambhir valley.

This discharge can, however, be utilized abundantly by means of inundation canals taken out from the river bed, after it has debouched from the hills.

The following are the existing works dependent on the Gambhir River in their order of position:—

(1) The Pichuna or Seola Canal on the left banks.
(2) „ Ajan Bund ... „ „ „
(3) „ Dhana Cut ... „ right „
(4) „ Ghata Canal ... „ „ „
(5) „ Bokholi Canal ... „ „ „
(6) „ Shekhpur Canal and other small spill channels.

On the 12th March 1904 with Mr. Devenish (late State Engineer) and Mr. Judd (the present State Engineer) I inspected a site about a mile above Biana, where a section had been taken across the River Gambhir, and my opinion was desired.

The catchment area here is about 1,100 sq. miles. The proposed dam would be about 12,000 ft. long, greatest depth of water 25 ft. The following reduced levels were stated :—

River bed R.	R. L.	77
Escape	„	102
Ordinary flood	„	104·5
Highest flood	„	107
Top of sluice	„	110
„ dam	„	117

The gradient of the river bed is said to be 3 feet per mile. The contour area of the proposed reservoir would be 6 sq. miles and the capacity 181 million cubic feet.

The total cost, including Rs. 65,184 for a masonry core-wall in the river bed, and Rs. 10,000 as compensation for land submerged, would be, it is stated, about Rs. 3,28,788.

If these figures are correct, it shows that only about 600 c.ft. water would be stored for one rupee, which is not satisfactory.

We went over the line from one end to the other. I agree with Mr. Devenish that the stream is too large and the valley too wide for a dam to be constructed across it here, except at prohibitive cost. (2) There is no good site for an escape here. (3) The river in flood must bring with it a great deal of silt, which would be a very serious question to deal with, and for these reasons I do not recommend any attempt to dam the river here.

Whether any better sites exist higher up I do not know, but am informed that they do not.

From what I have seen of the river in the Karauli and Jaipur States, I think it would be possible to dam it in the Karauli States: whether it would be advisable for the Karauli State to do so is doubtful, and is a matter requiring careful investigation, and depends upon the wishes of the Karauli Durbar. In the Jaipur State the banks are generally too high and the land on both banks too much cut up with ravines to attempt anything; but there is a place inside the Karauli border, near the point where it is crossed by the Karauli-Hindaun Road where, if political difficulties can be arranged, I think it would be possible to put a submerged weir and take a supply cut on the left bank from the river and it would then only be necessary to arrange for a suitable storage reservoir in the Jaipur State, but until levels have been taken it is impossible to say more.

In the Bharatpur State, as far as I have seen, the best way of dealing with the river is to take cuts from it, as Mr. Devenish has done.

On our way back from Bareta on 14th March 1904, we inspected the head works of the Pichuna Canal, which is taken out from the River Gambhir near the village Seola, with the object of flooding the Pichuna District when required, and if necessary to feed the Ajan Bund.

The head is well and securely placed in rock cutting two or three chains long. The supply is controlled by a regulator consisting of openings each 6 ft. wide, which can be closed by planks let into the cut stone grooves in the piers. The canal filled to a height of 6 ft. during the last monsoon, and the regulator worked all right.

The cut was opened for the first time in August 1902 and at present discharges into an old spill channel of the Banganga River, that leads ultimately into the basin of the Ajan Bund. By this means an annual supply to this important reservoir can be insured. It is now being extended towards Pichuna.

The Gambhir River appears to have deserted its old course almost entirely, and Mr. Devenish apprehends that there may be a considerable loss of prosperity, therefore, on the right bank in the Rupbas district. He proposes to avert this by cutting a channel 8,800 ft. long 30 ft. wide and 4 ft. average depth through the new deposit of silt that bars its former course, and this is now being carried out.

A better site has, it is said, been selected for both the bund across the river and for the diversion cut, and it is anticipated that it will be successful. Care will be necessary that there is no scouring action along the face of the bund as the floods pass, or that the face of the bund is protected against such action. No unprotected sand bund will stand exposure to a side current.

S. S. JACOB, Col.,
Consulting Engineer for Irrigation in Rajputana.

APPENDIX E.

REGARDING THE BARETA STORAGE RESERVOIR.

I inspected this fine storage reservoir with Mr. Devenish (late State Engineer) and Mr. Judd (the present State Engineer) on 13th March 1904.

The bund was begun by Lieutenant F. J. Home, R.E., in A.D. 1866, but work was stopped by the late Maharaja Jeswant Singh on his accession. Less than half was completed, the part across the nullah bed not having been attempted.

The work was resumed during the minority of H. H. Ram Singh when Colonel Loch was Political Agent, A.D. 1896. Owing in some measure to the famine of A.D. 1897 the work was rapidly completed.

The top of the bund is 10 ft. above the present level of the escape weir and 55 ft. above the river bed.

The catchment area is 70 sq. miles, the capacity of the reservoir at escape level (R. L. 680) being 1,359 million cubic ft. The water when the tank is full spreads over an area of about 4 sq. miles. The ducts had to be taken across a difficult piece of ground for about 2 miles before they reach fairly even land, and the way in which this has been done and the whole work carried out reflects credit on Mr. Devenish and on all concerned.

The old borrow pits at the rear of the dam, which were about 200 ft. wide and 8 ft. deep, have all been filled in, so that percolation water close to the toe of the rear slope has been removed, and the bund has been strengthened by the firm footing given to the bank. The stone pitching on the inner slope of the bund is exceedingly good.

In A.D. 1897 the bund filled up to R. L. 670, 10 ft. below escape level. In 1898 it filled up to R. L. 674, and in 1899 after 20 inches of rain the water overflowed the weir, reaching R. L. 682, and the surplus water ran for several days.

It is interesting to note the run off the catchment compared with the rainfall.

Year.	*Rainfall.*	*Run off per cent.*
1901.	25 inches. The water rose from R. L. 654·44 to 679·50, or 6 inches below waste weir level—19 inches of rain fell in July which accounts for the larger percentage stored	32
1902.	2½ inches on the afternoon of the 21st and night following—250 m. c.ft. water were received ...	70
1903.	20·43 inches. Water rose from 658·50 to 674·50, a rise of 16 ft.—the rainfall was very evenly distributed, the greatest for any month being 9 inches in August	22½

showing how the run off varies with the intensity and duration of the rainfall.

In November 1901 the estimated loss by evaporation and absorption is stated to have been about $\frac{3}{10}$ inch in 24 hours over the whole surface.

It takes about 1 inch of rain to fill up 1 ft. of depth at the escape level, supposing the run off to be about 60 per cent., as it is in heavy falls.

A residence is being built for the Durbar at the end of the range of hills on the south side, on a charming site looking over the lake and facing the north.

As regards irrigation the progress made and results obtained are most encouraging.

I think some improvement might result from a system of giving water by rotation, and by increasing the capacity of the ducts at the extremities, that each village shall get all the water it requires regularly, promptly and in full quantity; so that the branch may be closed and the water be passed on to the next village. If this is not done and the water is allowed to dribble away there will probably be wastage.

The only suggestions which occur to me are:—

(1) The advisability of raising the weir 2 ft. by a masonry wall on the present escape. The top of the bund would then be 8 ft. above it. The cost would be very small, and the capacity of the reservoir would be increased by 280 million cubic feet.

(2) Below the escape, the toe of the slope of dry stone would be stronger if protected by a row of large blocks of random rubble masonry made in situ and let into the ground a foot or so; artificial rocks, in fact, to prevent the smaller stone in the slope above from being washed away, if a flood ever came this way.

(3) An iron grating to be put in front of the outlet sluices to prevent any obstruction entering the valve or outlet. The iron bars should be put vertically (not horizontally) to facilitate cleaning at any time.

(4) Regarding the new residence—

(*a*) A terrace, open or covered, with ornamental stone balustrade all round might be put in front or where convenient. The view is beautiful, and such a place to enjoy would be pleasant,—or steps be provided to the flat roof.

(*b*) A campanile, turret, or chatri to break the horizontal sky line of the roof would make the building, which is well designed and well placed, more picturesque.

(*c*) The hole from which stone has been quarried near the site for the stables might be lined with masonry and used as a water tank.

(*d*) The hill sides and ground near might be filled in here and there with good earth and be planted with evergreen shrubs and creepers to overhang projecting rocks.

(*e*) The ground below near the edge of the lake might be laid out as a landscape garden, with rustic bridges, winding paths, arbours and seats, and some of the slopes be turfed down to the water's edge.

There are facilities for making a lovely place here. The Agency Surgeon (Major H. E. Drake-Brockman) is very keen about a drinking water supply being taken from the Bareta Reservoir, and although he considered it was fairly potable and suitable for a drinking supply after filtration, the sample sent for analysis was not considered fit by the Government Analyst for a water supply.

The next difficulty is, that the capital outlay of 8½ lakhs of rupees for a population of 44,000 is very large, especially when the water would have after all to be raised by machinery before distribution.

The question has been more fully discussed in the Appendix on the water supply to the city, page 39.

S. S. JACOB, Col.,
Consulting Engineer for Irrigation in Rajputana.

APPENDIX F.

REGARDING THE AJAN BUND.

On the 15th March 1904 I visited this bund with Mr. Judd, the State Engineer.

Mr. Devenish in his Report, dated February 1903, notes as follows:—

"The supply to this bund is now apt to be excessive. What is most needed is a slight raising and strengthening of the bank to give a margin of safety for the retention of heavy floods, pending the discharge of the surplus volume, at the same time limiting the supply to the basin, in order to prevent the possibility of so high a flood level occurring again within it."

The chief source of supply is stated now to be from the Gambhir River, which, having left its old course, spreads itself out over the left bank and adopts some of the old Banganga River spill channels. Formerly the river, which has a rocky catchment area of over 1,000 square miles, passed outside the south end of the Ajan Bund, and with the exception of the water obtained from an inundation canal, cut from the Gambhir River into the catchment of the Ajan Bund, no water was received from this river. The bund formerly was chiefly filled from the Banganga River.

In August 1902 a heavy flood occurred in the Gambhir; the river left its old channel and discharged itself into the Ajan Bund, which was already full. The sluices and escapes of the bund were not sufficient to cope with the high floods, and the bund was over-topped and breached in two places. Probably the top of the bund was not level throughout.

The top level of the bund has been raised to R. L. 590 everywhere throughout; the formation width at top has been made 12 ft. wide, with slopes of 3 to 1, and 2 to 1, and the capacity of flood discharge has been increased—

(*a*) To the existing waste weir at Kalyanpur have been added 12 openings of 6 ft. by 3 ft. 6 in. at R. L. 580.

(*b*) A new escape weir at Khokar, in the northern wing of the bund discharging towards the Bharatpur-Gunna, length 100 ft. with sill level R. L. 583, which can be closed by wooden planks in cut stone grooves.

This escape was inspected. The work seems to be well designed and well carried out.

The only suggestion I can offer is to put some dry stone pitching, let into the ground, below the lower wall of the water cushion to prevent any scouring out here.

The water discharged here will be stored in Kaladeo Jhil, and another escape is being added at Barah consisting of 10 openings of 5 ft. each. The total improvements and additions give an increased flood discharge of 12,680 c.ft. per second instead of the old discharge of 5,200 c.ft. per second.

		Rs.
The estimated cost of improving the old weir	...	2,300
„ „ building the new „ ...	...	9,000
The total cost of doubling the discharge...	...	11,300
And of all the improvements and additions ...	...	25,800

The State Engineer (Mr. Judd) reports that water first entered the bund on the 2nd August 1903, and continued to rise rapidly in the bund. On the 6th the waste weirs began to work.

On the 7th all the sluices were opened and remained open until the 13th. During this period 1 ft. to $1\frac{1}{2}$ ft. of water was flowing over the waste weirs, the flood reached a level R. L. 586, the level of top of the bund being R. L. 590 and of waste weirs 584·50.

On the 13th August the water fell below the level of the escapes. For six days, from the 7th-13th August, there was a discharge of 6,000 cusecs. The flood was regulated by the sluices, and no more water flowed over the waste weirs.

The Ajan Bund was in no way damaged.

As far as the eye can see, and for miles beyond, the country is covered with fields of ripening grain, showing how much good can be done by a proper system of inundation. Great credit is due to Mr. Devenish for the way he has successfully trained the floods of the Banganga and contributed to this result.

"The Bangunga River now flows along the Oochain-Biana Road, having left its former bed, near Farsu, on the left bank. The Bangunga floods are now controlled and utilized by a system of embankments and regulators, which divert as much of the water as is required for irrigation northwards, and let the remainder escape gradually eastwards, according to the principal fall of the country."

S. S. JACOB, Col.,
Consulting Engineer for Irrigation in Rajputana.

APPENDIX G.

REGARDING THE WATER SUPPLY.

Mr. Devenish (the late State Engineer) in his Note, dated 6th February 1903, on the future requirements and possibilities of Irrigation in the Bharatpur State says, "The question of a drinking water supply for the Bharatpur city does not pertain strictly to Irrigation, but the authorities of the Bharatpur State would do well to obtain advice on this subject from Sir Swinton Jacob during his visit.

The whole discussion that has taken place on the subject hitherto is contained in one file in the P. W. D. Office at Bharatpur.

Briefly, the only proposal approved generally has been for a supply from the Bareta Bund, and the chief objection to this proposal is the very large outlay that would be required to bring the water from a distance of 35 miles.

A gravitation channel to Sewar, where the water would be filtered and pumped into an elevated cistern commanding the city, is the main part of this scheme. The channel could be formed economically from local materials instead of using pipes."

No. 925, dated 27th March 1903.

The Agency Surgeon, Major H. E. Drake-Brockman, I.M.S., sent me for information a copy of a letter he had addressed to the Secretary to the State Council, Bharatpur, last year, 1903, from which the following extracts are taken:—

"I have the honour to bring to the notice of the State Council the excessive mortality which has prevailed amongst all classes in the city of Bharatpur during the year 1902, more especially during the autumn months.

The mortality per mille in this city reached the high figures of 73·35 in a total population of 43,601, being 6 times that for the district. This does not by any means represent the mortality for the autumn months, which reached a far higher figure.

The total mortality for this city alone was about half what it was for the whole State (*e.g.* 3,198 against 7,813), which shows forcibly, even allowing a large margin for the extra mortality always expected in cities as compared with the district population, that there are local conditions in this city which must account for such.

If further proofs were needed, I may say that the mortality amongst children under one year has been little short of appalling, which fact, quite apart from any errors resulting from faulty registration of vital statistics, is borne out by the experience of the Vaccination department, and which if allowed to go on unchecked will speedily result in extermination of the population altogether, and this, from my experience and intimate knowledge of the place, I can say is by no means a pessimistic view of the case.

The reasons for this excessive mortality are not difficult to enumerate * * * it is due directly to water-logging of the soil in and around the city of Bharatpur, the result of indiscriminate flooding, not irrigation, of the land about the city from the flood water of the Ajan Bund and filling up of the Fort Moat inside the city.

I have, as you know, steadfastly set my face against this inundation for many years past, but my warnings in the matter have not been paid any attention to hitherto, with the result that this year we have a state of things which is fairly startling and will assuredly call for some comment from the Government of India when the vital statistics dealing with the city eventually reach them * * * *

A mortality per mille of 73·35 for the year suffices to show that there must be some serious mal-hygienic conditions prevailing to account for such, and from my long experience of this place and its neighbourhood, I can confidently say that it is almost solely due to the causes mentioned above and no other, and what is more, causes that can be more or less remedied.

The statistics by no means exaggerate, in fact they really considerably under-estimate the amount of havoc done: those that have escaped actual death from fevers have had their constitutions so utterly shattered and devitalized by the profound blood deterioration and anæmia resultant upon malarial saturation, that they fall easy victims to any intercurrent ailment, thus markedly swelling the death roll of this city * * * *

The mortality amongst the children under the age of one year has been enormous. But few have escaped, and of those that have escaped I have found the blood of many infested with malarial parasites; so that the coming generation of this population of the city are becoming a devitalized and miserable lot, which augurs badly for the future health and prosperity of the place, even should they survive ultimately by being gradually immunised to malaria, which is extremely doubtful.

Moreover, the birth rate, owing to all the devitalizing conditions present, is seriously affected, which is a factor ultimately likely to prejudicially affect the welfare of the city.

I think I have said sufficient to bring the gravity of the situation before the notice of the State Council. I will now briefly detail what I am firmly convinced are the remedies for the present very unsatisfactory state of affairs.

The two great mal-hygienic factors which so seriously affect the public health of this city are—Firstly, inundation round the city and Khaie; and Secondly, the presence of that sink of iniquity the Fort Moat. There are other causes all directly dependent upon these two, such as bad drinking water supply and water-logging of the soil within city walls, and consequent sudden raising of the level of the sub-soil water of the ground within the city, with all its evil effects; and the presence of kunkar pits in large numbers close to the city, which I will briefly touch upon also.

As regards the indiscriminate flooding of the lands around the city, within two miles for instance, I hold that this is not only unnecessary, but is, under present conditions, suicidal policy on the part of the State Council to allow, as the loss that such produces to the State by death and sickness of its officials, civil as well as military, with consequent absences from duty for long periods often, is incalculable, leaving aside the misery and death that follow in a large number of cases.

Flooding of any lands *for any purpose whatsoever* within a radius of two miles of this city should be made criminal and absolutely prohibited; the paltry amount of revenue realized would barely more than half pay for quinine which would have to be purchased to mitigate the ravages of malaria produced as a direct result of such procedure.

As regards the Fort Moat, under present circumstances it is necessary, I admit, to fill it once a year, in order to keep up the level of all the drinking wells inside this city; but this could and ought to be done without the indiscriminate flooding which is allowed to occur after opening the Kunj Behari Mori on the Agency-Sewar Road; and if at present impossible, a conduit without delay be made from that mori directly into the Fort Moat.

This would effectually prevent the flooding which yearly occurs around and about the south of the city, in the vicinity of the so-called Atal Bund.

I emphasize the fact that on no conditions whatever should any flooding or water be allowed to creep within, that is to the north or city side of the Agency-Sewar Road.

Another point in this connection, and one regarding which early orders should be made by the Council, on sanitary grounds, to the State Public Work Department, is that the Fort Moat should not be filled, as was done this year (1902) till towards the *end* of the monsoon, and then only very gradually, and after consultation with the Agency Surgeon. This is important on sanitary grounds, not the least of which is, that by rapidly filling it, the level of the sub-soil water is so rapidly raised as to be extremely detrimental to the public health, and this interesting point is borne out by the fact that there is at present in this city a very excessive prevalence of diseases which are directly attributable to a water-logged soil and a high ground-water level, *e.g.*, phthisis, rheumatism, heart and chest complaints.

To my mind the remedy is a very simple one scientifically, and I am informed it is by no means, considering the importance to the welfare of this unfortunately placed city, a very impossible scheme financially: it is the question of supply of good drinking water to this city. This is a measure of most vital importance to the public, and were it inaugurated would revolutionize the place.

The present supply is derived from wells situated in a salt-bearing strata, and in soil permeated and saturated with an enormous amount of organic matter, which, as the hot weather approaches, becomes extremely

unpalatable, and being impregnated with an enormous amount of inorganic as well as organic matters, sets up digestive troubles, &c., and causes mal-assimilation and mal-nutrition, which in due course become important factors in devitalizing the people.

A scheme of water works would once and for all do away with the necessity for filling up the Fort Moat, thus obliterating a pestilential focus for the spread of disease, and a most potent factor in the dissemination of malaria, by giving facilities for the breeding of Anopheles mosquitoes, and that too in the very midst of a crowded population, at the best of times deprived of fresh air by the presence of the ramparts round the city.

The bed of the moat could, with much advantage, be then turned into a garden, and all the water coming into the city would be under complete control, the advantages on the public health resulting from such a supply being difficult to gauge.

To my mind, the time has come to seriously consider the necessity for providing a supply of good drinking water by means of water works, and the splendid reservoir at Bareta has been proved to be more than equal to the occasion; moreover it contains the best water for such a purpose to be found in this State.

Were such adopted, it would once and for all put a stop to inundation or the necessity for filling up the Fort Moat, which I consider a most obnoxious spot from a sanitary standpoint, and would revolutionize the place altogether, the far-reaching effects of which on the welfare of this city it will be impossible to foretell.

The question of a water supply from Bareta has been discussed, but the matter has never been thoroughly thrashed out from the Engineering point of view. An Engineer specially qualified in such matters is required to give an opinion, and I would take this opportunity of again urging upon the Durbar, with all the means in my power, the urgent necessity for early action in this matter, to prevent any repetition of what has occurred this year; and if necessary a Committee be appointed to seriously discuss and take the matter up at an early date, taking advantage of the advent of Sir Swinton Jacob, if necessary, to go into the scheme, and if possible adopt some measures to protect the public health.

Until this is done, however, it would be advisable to have that channel constructed from the Kunj Behari Mori direct to the Fort Moat, and issue strict injunctions to the Public Works Department that no flooding of land whatever is to be allowed within the Agency-Sewar Road; and that the medical authorities be consulted before the Fort Moat is filled yearly; and these measures only, failing the realization of the water works scheme, of which I strongly urge the early completion."

As regards the project for a supply of good drinking water, on the 25th May 1899 the Secretary to the Council addressed the State Engineer on the subject. He states: "The city being situated in a very low and damp ground, water is collected in the rainy season all round, which makes the air impure, and even does greater harm when used by the people.

When there are no rains, the wells fail to supply a sufficient quantity of water. The soil being saltish, the water in most of the wells is naturally such.

A few wells which have sweet water are those round the moat or those near a tank. Their supply of water altogether depends on the rain. When the rain is scanty, the water of these wells also becomes saltish, so the people undergo great trouble.

For removing these wants, I propose that a store of water may be kept, and that store I think cannot be better kept than in the moat which may be well filled up by bunds, and then this water may be cleared in a large pucca tank, which may be built up at a place whence water may be supplied to all the city by water-pipes.

Well-to-do persons will have water-pipes in their houses by paying for it, while the people at large will get water without any difficulty. It will also be not improper if they are made to pay for it.

Although in the beginning the State will have to undergo expenditure for the comfort of its people, yet that money which will be thus spent, I think, can shortly be recouped by laying a light tax, which people will not feel, considering the ease and comfort in getting water. At the same time this will greatly improve the sanitation and climate of the city.

In my opinion the State should spend money in this useful work, as it does in many other cases for the benefit of its people, and this expenditure also can, however, be best met by curtailing other expenses."

Copy of Letter No. 947, dated 31st May 1899, from the Executive Engineer, Bharatpur State, to the Member and Secretary State Council, Bharatpur.

In reply to your letter No. 1077 of 25th May 1899, regarding the Bharatpur water supply, I am glad to have an opportunity of stating that I agree with your opinions as to the deficiency of the existing water supply and the desirability of improving it.

As you have remarked, the drinking water of the city and neighbourhood is obtained entirely from wells which become brackish unless replenished by percolation from adjacent sources.

Outside the city these sources of replenishment are generally "diggies" or excavated tanks which are filled with water in the rainy season.

Inside the city the principal sources are the deep moat round the Fort, and outer ditch round the ramparts.

The moat and the ditch and the diggies are all filled in years of good rainfall by water collected in the neighbouring depressions, and these depressions (the largest of which is the Atal Bund) are supplied partly by local drainage but chiefly by flood water from the Banganga River.

The floods of the Banganga River are controlled and distributed by a system of embankments or "bunds," so that the depressions can be swamped to any required extent by opening sluices in the bunds.

The depressions have also been drained, so that the water flooding there can be reduced or run off at will.

The moat is generally filled by a channel from the Atal Bund, and in any year, unless the floods fail altogether, as very rarely happens, the Atal Bund can be filled from the immense quantity of water collected by the Ajan Bund.

One filling of the moat will last two years, so that the moat is a fairly secure and constant reservoir.

The moat can also be filled by water from the Motijhil Bund, but the Motijhil has been empty for the last three years, and it is only filled in years of high flood by drainage from the Ruparel spill.

The quantity of the water supply obtained by the system desired is undoubtedly bad. Firstly, the flood water is impure and likely to be impregnated with materials germs; Secondly, the reservior or basins in which it is stored, *viz.*, the moat, ditch and the diggies are contaminated in every possible way. No attempt is made to keep them free from sewage. The water in the moat remains fairly clear owing to its large volume, and it is not more impure than the tanks and reservoirs, from which natives of this country usually obtain their water, but it is not pure enough to be potable, and though some natives of the city drink it, most of them draw their drinking water from wells.

A considerable quantity of foul water and sewage is discharged into the moat.

The water contained in the "diggies" is worse than the moat water; and the ditch round the ramparts is a mere cesspool.

The water obtained from wells which are supplied by percolation from these sources is generally potable, according to analysis made regularly by the State Medical officers, from which fact it is evident that in most cases efficient natural filtration takes place through the subsoil.

The third source of contamination is in the wells. These are used freely without any protection from contamination, the only possible way of securing a well from outside contamination being to seal it and draw the water by pumps.

Fourthly, besides contamination from organic sources, when the water level is low and the deep openings or the water level is low and the deep springs or water-bearing strata are tapped, the superficial water-bearing

layers being nearly exhausted the water in the well becomes highly brackish, because the deep springs are generally impregnated with various inorganic salts derived from the soil, especially with common salt.

It is an easy matter to thus describe the deficiencies of the water supply of this place, and easier still to infer the desirability of a better system, but as Bharatpur happens to be situated it is not so easy to suggest the ways and means of improvements.

There are no contiguous hills in which a deep reservoir could be formed.

The nearest possible source of supply from a deep reservoir would be the Bareta Bund, 25 miles distant.

The supply there appears to be ample, but the cost of carriage of the water would probably be prohibitive, and water would require filtration to render it potable. The scheme suggested by the Rai Sahib Sohan Lall of taking the water from the moat, filtering it and filling a supply reservoir from it is more feasible, but it is a scheme requiring most careful consideration and elaboration, which should not be accepted until it has been approved by the highest available Engineering and scientific authorities.

It would be possible to sink one or more large wells, which would be fed by percolation from the moat to seal these wells, and establish pumping apparatus to deliver water from them into a filtering reservoir.

From the filtering reservoir it would pass after purification into a storage reservoir sufficiently large to hold at least two or three days' supply, and high enough to command all parts of the city.

A main with the usual branches, valves and distributary pipes would be connected to the reservoir for the supply of the city and neighbourhood.

The water would probably not only require filtration, but also chemical treatment to reduce the hardness and inorganic matter contained in it before it would be accepted by sanitary authorities as suitable for a public supply.

Supposing that at any time the State Council is in a position to definitely entertain the scheme, having funds to the extent of say two lakhs of rupees available to meet the cost of it, they should apply to Government for the advice of an Engineer specially experienced in water supply, to confer with the State Engineer and to advise the Council of the most feasible way of meeting their requirements.

The administration of Rajputana would not allow a large scheme of this nature to be embarked upon without full consideration and favourable opinion from the highest Engineering and Sanitary authorities.

Extract from a Preliminary Note prepared by Mr. Devenish, late State Engineer, on the Water supply project accompanying his letter No. 2980, dated 19th June 1901, to the Political Agent, Bharatpur.

"Supposing that the cost of a supply from Bareta is considered prohibitive under present financial circumstances, it is nevertheless possible to obtain a fairly potable drinking water supply for the population from the existing wells in the construction of which a very large capital outlay has been expended from time to time. There are about 150 masonry wells described as sweet, and about 250 brackish within the city and environs.

These wells would continue to be used whether a pipe water-supply scheme was adopted or not, possibly they would be principally used in preference to an imported supply on account of habit, taste, or convenience. Chemical and bacteriological analysis prove that many of the wells yield potable water of a fair quality in spite of the risk of contamination to which they are subjected.

In my letter No. 947 of 31st May 1899, addressed to the Secretary State Council (copy herewith attached) I have written a full description of the system of replenishment of the well source. In brief, the drinking water wells are all more or less brackish, and they depend for their comparative freshness on percolation from neighbouring accumulations of flood water in swamped depressions or in excavated tanks or diggies. The moat round the Fort which is filled annually with fresh water from Banganga floods, influences all the wells in its neighbourhood. The sources of replenishment to the wells, whether from the moat or otherwise are all more or less impure, but the fact that any of the wells do not show objectionable terms of organic impurity, shows that there must be fairly effective natural filtration through the sub-soil.

Twenty to fifty wells thus protected would probably afford a sufficient supply of uncontaminated water for all those people who would consent to use the pumps, though it would be impossible to stop the custom which has continued from time immemorial of the women drawing water for their households with ropes and pots from an open well.

Their custom would certainly continue in Bharatpur for many a day whatever other water supply might be available. It would be a great thing, however, to have a sufficient number of wells the purity of which could be depended on, especially in a time of an epidemic, when the unsealed wells might be temporarily blocked and disinfected.

I strongly recommend the adoption of this course to the authorities concerned, whether any more elaborate scheme is favoured or not.

Objection has been taken by the Agency Surgeon to the flooding of the low ground in the vicinity of the city. It is from the flooded depression known as the Atal Bund that the Fort Moat is filled. The flooding is doubtless insanitary when it is excessive, but it can be controlled, and for the purpose of filling the moat only an insignificant area of land need be flooded, amounting to about 100 acres.

As this land dries up and is cultivated in October, no harm can come from the Atal Bund flooding, provided that it is judiciously regulated.

The moat and the diggies are used for washing purposes and for watering cattle; it is therefore necessary for the comfort and health of the people to fill them yearly.

The Ajan Bund is, as mentioned by the Agency Surgeon, quite unsuitable for a storage reservoir, and as far as I am aware it has never been suggested for a drinking water supply. It is 12 miles long, with 14 square miles of waterspread when full, averaging only 4 or 5 feet in depth. The basin is dry and under cultivation in October.

This information is enough to put the question of its use for a drinking water supply out of further discussion.

If the want of funds should be at present an unsurmountable objection to a water supply from the Bareta Bund, there is this consolation, that there are many other desirable sanitary reforms affecting the public health which are awaiting attention, and it is generally agreed by sanitary authorities that conservancy, drainage, &c., should precede water supply.

On the other hand a pure water supply system is generally considered to be an essential mark of sanitary progress.

I am aware that the medical authorities consider it most important, and it appears that local public opinion is all in favor of it in spite of the necessary heavy outlay.

The Bareta Bund is capable of yielding an ample and satisfactory supply. I shall be very pleased to receive instructions to prepare a project from that source, after the questions discussed in the preliminary report have been duly considered by the administration of the State."

Copy of Letter No. 1846, dated 6th February 1902, from the Executive Engineer Bharatpur, to the Political Agent, Eastern Rajputana States, Bharatpur.

In compliance with your letter No. 574 of 30th ultimo, I have the honor to return the preliminary note, after noting the marginal remarks.

I have added in pencil such notes as seem called for, in explanation of the matters in question.

The estimated cost is certainly very high, but I fear that it cannot be much reduced. The sum of 8½ lakhs, however, should be the total ultimate cost, and it would be possible to reduce the initial cost to about 1½ lakhs.

Mr. White, Superintending Engineer and Secretary to the Agent to the Governor-General, went through the scheme personally with me, and after a visit to the Ajan Bund he seemed to think that the Bareta Bund

was the only possible source of supply, the Ajan Bund basin being by far too shallow for water storage.

The site proposed at Sewar for a service reservoir was inspected and approved of by the Superintending Engineer.

There is a large masonry tank there which could be utilized for a settling tank, and I think that the item of $1\frac{1}{2}$ lakhs estimated for pumps, service reservoirs and filters might be reduced to 1 lakh, and the initial outlay in distributary pipes to $\frac{1}{2}$ lakh, but in the other items I doubt that much reduction is possible.

Regarding drainage which is indeed a necessary accompaniment to water works, my opinion is that the Bharatpur city and suburbs are amply served with drains already, and I do not know of any additional drainage that would be rendered necessary.

All surfaces above the drainable level are drained. Accumulations of stagnant water in ditches below the drainable level, such as the ditch round the ramparts, can only be removed by filling or by pumping or by keeping water out of them.

A drinking water supply would not affect them. I do not think that Bharatpur is likely to suffer from want of drainage in future, though it has in the past, owing to the old drainage system having been neglected. There is a very good system of drains in the city which was constructed during the previous minority and since then new extensions have been made.

Extract from a Note on the scheme for a Water supply to the City of Bharatpur from the reservoir at the Bareta Bund, by the Agency Surgeon.

I would take this opportunity of most strongly deprecating any extensive expenditure by the Durbar upon improvement of wells, &c., as an alternative measure, or otherwise, as I believe has been suggested from more than one quarter, as such would result in a complete waste of money, which latter might with much advantage be reserved for the more efficient, more sanitary, and in fact only drastic and efficient solution of this problem of a water supply for this city as no other scheme but the Bareta Bund supply would or could give this city a really potable and hygeiant drinking water, owing to the fact that it is the soil itself in and around this city which is redolent with organic and inorganic matter to such an extent as to render all water which may happen to come into contact with it impotable. For this there is absolutely no remedy except to import water from a site at which such cannot occur, and I maintain that in this State no such opportunity exists anywhere except at Bareta, whence the supply in this instance should most certainly be drawn. Finally, I may add that this scheme to provide for a pure drinking water supply to this unfortunately situated city, is one which, if ever pushed through to the stage of realization, is likely to have far-reaching effects, and influence the prosperity of the place, and perhaps State, in many ways other than the

more possible extinction of water-borne diseases, which form the most deadly variety of such in this country. I have personally known natives say that this mere factor, *viz.*, the absence of good drinking water in the place, has deterred a great many from coming and settling down here. This is hardly to be wondered at when one considers what a very important part water plays in the domestic economy of the native of India, and hence I may say, from a fairly intimate experience of this place, that the greatest interest and anxiety are being displayed at the present time by the residents of this city as to whether this much-to-be-desired and urgently needed sanitary reform is ever to be realized in the near future.

Copy of Letter No. 4769, dated Bharatpur, the 4th October 1902, from the Executive Engineer, Bharatpur, to the Members and Secretary State Council, Bharatpur.

In reply to your letter of the 26th ultimo regarding a drinking water supply for the Bharatpur city from the Ajan Bund, I write to say that the Ajan Bund is not suitable for the purpose.

A very large quantity of water is received in the Ajan Bund every year, but the depth that can be retained is not more than 8 or 9 feet at the deepest place, or 3 feet on an average over the whole waterspread, whereas the depth of water that would be evaporated and absorbed during a year would be about 8 feet.

Besides this the Ajan Bund water is not of good enough quality for drinking. An excavated reservoir would not hold nearly enough water for a year's supply, excepting the city moat which is not approved of for sanitary reasons. Under these circumstances I do not know of any better scheme than the Bareta Bund scheme for the Bharatpur city.

Unfortunately there is no suitable reservoir for storage nearer. The expense of it is undoubtedly very heavy, and it is for the State authorities to consider whether they could embark on it or not.

If the Government of the United Provinces would guarantee a constant supply from the Agra Canal to feed a small service reservoir, this would be the cheapest scheme, but there are many difficulties in the way of it, and on the whole question I think that if the State authorities are not satisfied with the present supply from wells they will be obliged ultimately to adopt the Bareta scheme.

The advice of the Government may be sought on the question.

Report of Analysis of water taken from the Bareta Reservoir by the Government Analyst, United Provinces of Agra and Oudh, accompanying his No. 46 An., dated Agra 24th February 1904:—

Number.	Copy of Label on Bottle.	Total solid grains per gallon.	Chlorarie grains per gallon.	Total hardness grains per gallon.	Fixed hardness grains per gallon.	Free Ammonia parts per million.	Albuminated Ammonia parts per million.
1	A corked w.qt. bottle of water without any label thereon	30·8	3·5	...	...	1·28	·50

Unfit for potable purposes.

I have purposely made these long extracts, as the subject is such an important one, and it is well to have on record the opinions which have been expressed.

No one can see the places and read the above papers without being impressed with the necessity of something being done to prevent the flooding of the land near the city, and of the urgent need of a better supply of good drinking water.

The indiscriminate flooding north of the Agency-Sewar Road should certainly be stopped, and a channel be made to convey the water direct to the moat and the supply be under control.

A "diggie" or kund might be made at the lowest place to retain a supply of water for washing clothes, if considered necessary, until a proper Dhobis' Ghat can be constructed.

I understand an estimate for this channel has been submitted by Mr. Judd (the State Engineer), and it only remains for the Council to sanction it.

There will still be the surface drainage between the Agency-Sewar Road and the Atal Bund to deal with. This may not be much, but if it is not provided for it will probably collect outside the "Diggie" alluded to above. This may perhaps be remedied by cutting a channel, so as to drain this area, and lead the water direct to the Diggie; or prevent it from spreading over the surface in a shallow pool, which is very objectionable.

As regards a supply of good drinking water the following seem to be the only ways of meeting this difficulty :—

(1) From the Storage Reservoir at Bareta.

(2) „ „ Agra Canal to feed a small service reservoir.

(3) „ „ wells.

Regarding (1) the objections are :—

(*a*) The cost ; about 8½ lakhs af rupees.

(*b*) The long distance of duct or pipe, 24 miles, by which the water would have to be brought.

(*c*) The aqueduct would have, for some distance, to be taken across the sandy and ill-defined beds of two large rivers, the Bangunga and the Gambhir.

(*d*) The impossibility of keeping the basin of the Bareta Reservoir free from contamination, owing to the villages, cattle, &c., which exist.

(*e*) The difficulties which are sure to arise sooner a later between the needs of the city and the demands of Irrigation.

(*f*) The fact that the water on reaching Sewar would still have to be raised by machinery.

(*g*) The fact that the water is declared by the Government Analyst to be unfit for drinking.

As regards (2) :—

(*a*) In the first place it would be necessary that the Government of the United Provinces should guarantee a constant supply, which it would be almost impossible for the Government to do in the face of the demands for Irrigation, &c.

(*b*) The water would be always liable to contamination.

(*c*) The water would still have to be raised.

(*d*) The water might fail when most urgently needed for the above reasons. I do not recommend this.

As regards a supply from wells :—

Shallow wells are those which are sunk comparatively but a short distance into a superficial water-bearing stratum, and are supplied by the infiltration of rain and other water which falls on the adjacent surface of the ground, or which is drained from ponds, cesspools, sewers, rivers or other reservoirs and channels.

There are manifest objections against wells of this class if situated in the neighbourhood of towns, cemeteries, highly-cultivated lands and other sources of organic matter with which the water is liable to become contaminated.

Localities may frequently, however, be discovered where the conditions are favourable for sinking shallow wells, and where at the same time the water will be wholesome and comparatively pure. They are frequently sunk in the vicinity of rivers and lakes, and are supplied by the water filtering through the sands, gravel or rocky detritus which form their margin.

Deep wells are those supplied by water which has to percolate and filter through large masses of the earth's crust, and has therefore

been considerably modified in character by the substitution of soluble mineral matters for the organic and other impurities it held, when previously in the state of river or other drainage water.

The difference then between shallow and deep wells, as properly understood, consists rather in the greater or less distance of the source of the water which flows into it, than the actual depth of the well.

Bharatpur is probably too near the edge of the Gangetic basin for any hope of an Artesian well.

I cannot help thinking that a supply of good drinking water might be obtained from wells, perhaps shallow wells in quantity, sufficient for all requirements of the city. The direction in which I would suggest enquiry should be made, is on the west, north-west, and south-west.

The general slope of the country is from this direction. Wells with sweet water are known to exist, and it is out of reach of contamination from the city. Investigation should be made to mark these localities and to see how the water level in the wells compare one with another; also when the water is drawn what is the rate of infiltration and other useful data.

A *deep* well might also be made as an experiment in some position where it could be made use of for the Imperial Service troops or some other service; and tested to see what amount of water it would yield. The samples of water ought also to be analysed.

There is one thing about wells, shallow wells more particularly; the yield of water may often be increased and made constant by making a storage of water such as a tank on the surface above them. In this particular case there is always a certainty of the annual floods of sweet water of the River Banganga and perhaps the River Gambhir also to replenish any surface storage.

There is also a low range of high ground on the west of the Imperial Service Lines on which a service reservoir might be made for storing a few day's supply. Pumps would be required in any case to raise the water. But if the water is found to be good there is the means of increasing the amount to any extent, as required, either by sinking more wells or driving headings in them. They would all be connected by a pipe below the water level, and would drain into the deepest well which serve as a sump for the pumping engine. The long lead of canal or duct from Bareta would be unnecessary, and the water would always be free from contamination of any kind.

I am not sufficiently acquainted with all the circumstances perhaps to speak with authority, but I would suggest the matter be taken up in earnest, and a thorough examination of the ground be made by some specially qualified officer.

There is no question of the great need of a supply of good drinking water. The papers I have quoted give briefly various opinions which have been expressed, and as the matter was brought to my notice I have made these remarks.

S. S. JACOB, Col.,
Consulting Engineer for Irrigation in Rajputana.